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Optimal timing for introducing a new high-tech product: A Real Options approach

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Nota Biográfica

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Ainda em 2013 ingressou na SONAE SGPS na área de Planning and Management Control, onde se encontra desde então.

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Sumário

A indústria tecnológica é um mercado de grande crescimento com algumas particularidades, uma vez que contém alta incerteza, é composto por uma competição agressiva com a possibilidade de entrada de competidores desconhecidos e, por vezes, duas tecnologias diferentes podem estar a competir por um mercado sendo uma substituta da outra.

O objectivo desta dissertação é determinar o tempo óptimo para o lançamento de uma nova geração de produtos. Apesar dos modelos existentes, em Opções Reais sobre o tempo óptimo para a entrada num mercado, ser aplicável nalguns mercados, existem outros que são deixados de fora por estes modelos, já que a maioria destes trabalhos assumem que o valor dos seus projetos aumenta sem se considerar o ciclo de vida do produto (o que não acontece em todas as situações). Nalguns casos, como a indústria tecnológica, há sempre alguns produtos a serem lançados e o valor dos produtos mais velhos começa a verificar uma inversão na sua tendência para crescerem. Dado que a venda dos produtos mais velhos começa a verificar uma descida depois dos novos estarem no mercado, acreditamos que os cash-flows irão crescer até um ponto, a partir do qual começm a decrescer.

A inovação trazida por esta dissertação relaciona-se com a introdução de um modelo em que os *cash-flows* crescem de forma diferente do ciclo de vida dos produtos, até que a empresa lance um novo produto. Quando isto acontece, os *cash-flows* do produto antigo crescem a uma taxa diferente da anterior (eventualmente uma negativa) e os *cash-flows* do novo produto podem crescer a uma taxa diferente da do primeiro produto, uma vez que o mercado é agora mais maduro e tem uma procura maior.

Abstract

The technological industry is a high growth market of great value with some particularities as it is a market with high uncertainty, has an aggressive competition with hidden competitors probability of entrance, and sometimes two different technologies may be competing for one market, as one is a substitute of the other.

The main purpose of this dissertation is to determine the optimal time to launch a new generation product. Although the existing work about optimal timing to enter a market, in Real Options, may be applicable to some markets, there are others that are left outside of these models, as most of these researches assume that the value of their projects will increase without considering the product life-cycle, which does not happen in every situation. In some cases, such as the high-tech industry, there are always new products emerging, and the older products' value starts to see an inversion on its tendency to grow. Given that the product being sold by the company will see its sales starting to decrease after a new product enters the market, we believe that the cash-flows will increase only until a certain point, after which they will start to decrease.

The innovation brought by this dissertation is met by the introduction of a model where the cash-flows grow without considering the product life-cycle until the company releases a new product. When this happens the cash-flows of the old product will grow at a different rate from before (eventually a negative one) and the cash-flows of the new product may evolve at a different rate than those of the first product as the market is now more mature and has a higher demand.

Chapter 1

Introduction

The technological industry is a high growth market of great value. According to Yahoo Finance[1] five of the biggest ten companies listed in public exchanges are related to computing and technology. Nowadays, consumers are getting more and more into the usage of high-tech goods and services. At the end of 2004 Facebook had one million users, a number that increased every year until, in September 2012, the number of users was over one billion. In 2008 the worldwide total of smartphones sold was near the 140 millions of units[2], whilst in 2012 that number increased to almost 1,747 millions of units[3], an increase in sales that shows the growing importance of this industry.

But these numbers are not only high in the smartphones' markets and social networking companies: PricewaterhouseCoopers (PwC) estimates that in 2010 the global video game industry was worth about 56 billion dollars, being twice as high as the music market and about three fifths of the film industry. PwC predicts that the video game industry will become the most growing form of media throughout the next years, reaching 82 billion dollars in 2015[4].

The High-Tech industry also has the fastest growing rate (5.1%) when compared to all of the other industries and the High-Tech services demand for office space is growing at 3.7 times the rate of office-using employment categories[5].

The high-tech industry is largely based upon research and development, and is worth billions of dollars, as some of the world's largest companies are high-tech producers. Being a highly-competitive market, it is common to see fast paced dis-

[1] See `http://ycharts.com/rankings/market_cap` at 6th of November, 2012

[2] See `http://www.gartner.com/newsroom/id/910112` at 4th March 2013

[3] See `http://www.gartner.com/newsroom/id/2335616` at 4th March 2013

[4] See `http://www.economist.com/node/21541164`

[5] See `http://www.us.am.joneslanglasalle.com/ResearchLevel1/National_High-Tech\%20Industry_Office\%20Outlook.pdf`

coveries being made and new products being released with large improvements over their predecessors. These companies usually launch a new product when there has been some technological evolution that justifies it, and the product that was already in the market starts to become obsolete. When a new product is launched the consumers turn to buy it instead of its predecessor, whose sales start to decrease at a quick rate. Sometimes these companies choose to lower the price of the oldest product in order to soften the decrease in sales, trying to reach a market that seeks a lower-cost product. Most of the times this strategy is even combined with the strategy of selling the older product in emerging countries where the purchase power was not enough to buy the product before, and the consumers are still not capable of buying the new one in great quantities. Sometimes lowering the price of the old product will attract new consumers to the market because of the effect that the massive use may have on the product. For example, when a second generation of DVD players was released the oldest generation saw a decrease in their respective prices, which led them to reach a wider range of consumers. This led to an increase in the demand for DVD's, which led to an increase of movies featured in DVD's, and the new generation of players benefited from it, since it is more appealing to spend money buying a DVD player when there is a greater offer in DVD's.

This launching of a new product occurs when the producer understands that the technology has evolved enough since the time their last creation was released and it is time to upgrade their product. Each time a new product is released it is called a generation. When a producer starts a new generation, by releasing its fresh new product, gains the monopoly of that generation until a competitor enters that market. This happens because most of the target consumers will stop buying the last generation products (although it is important to remember that the company may decide to lower the price of the older product in order to attract costumers with a lower purchase power) and will either buy the only current-generation available product, or will wait for its competitors and choose from a wider range of products. Thus launching earlier a product has its disadvantages too as the rivals will know what technology was chosen to build that product and will have the choice to replicate it at a lower price (since technology components lower their price on a regular basis) or to have a more technological-advanced product (because there is technological evolution every day). But what really happens to the old product? Do two generations of the product share the market in equal parts? When should a company introduce a product and make the old one obsolete?

There seems to be an increasing number of researches carried on Real Options, most of them are about the optimal timing to enter a certain market, and still, there seems to be little investigation concerning the high-tech industry. This business has some particularities as it is a market with high uncertainty, given that it depends highly on the results of research and development; it is a market of high growth which means that the company must be able to keep up with the pace of the changes taking place. The business also has an aggressive competition with the probability of entrance of hidden competitors. It is usual to see companies in court proceedings, in what is now ordinarily called patent wars. Also, sometimes two high-tech industries have two different technologies that are competing for one market, and one is a substitute of the other. In this case usually only one technology will be accepted and gain the market. Usually the technology that wins is the one that achieves a great share of the market first. This was the case of some format wars (VHS vs. Betamax and Blu-Ray vs. HD-DVD). In a market with these characteristics the decisions taken by the companies become of a great importance, namely the choice of the perfect timing to introduce a new product. If the company releases its product too soon it will affect the sales of the older product and will allow the competition to either replicate it at a lower price or have a more technological-advanced product. If the company releases the product too late it will allow the competition to enter the market and affect the company's reputation as well as secure the advantages of being a first mover.

A practical example of how the new product affects the sales of the old ones is the Sony Playstation brand sales of home gaming systems. The first Playstation was released worlwide in 1995. In its first year on the market, 4.3 million units were shipped. This number increased every year until the Playstation 2 was introduced in 2000, selling 10.61 million units. The Playstation 2 followed the success of its predecessor, and in 2006 Sony released the Playstation 3. It is possible to observe the effects of what was described before in the Figure 1.1.

In Figure 1.1 PS1, PS2 and PS3 mean, respectively: Playstation (1^{st} generation), Playstation 2 and Playstation 3. "C1" means the introduction of PS2's competitors (Microsoft Xbox and Nintendo Gamecube) and "C2" means the introduction of PS3's challengers (Microsoft Xbox360 and, later on, Nintendo Wii). Notice how the PS1 sales start to decrease after the introduction of PS2 and Sony opts to stop selling it six years after the release of the new generation. PS1 does not seem to be affected at some point by the introduction of competition because the competitors released their products at almost the same time (Sega Saturn was launched three months earlier and Nintendo 64 was launched one year later, when this generation was still growing).

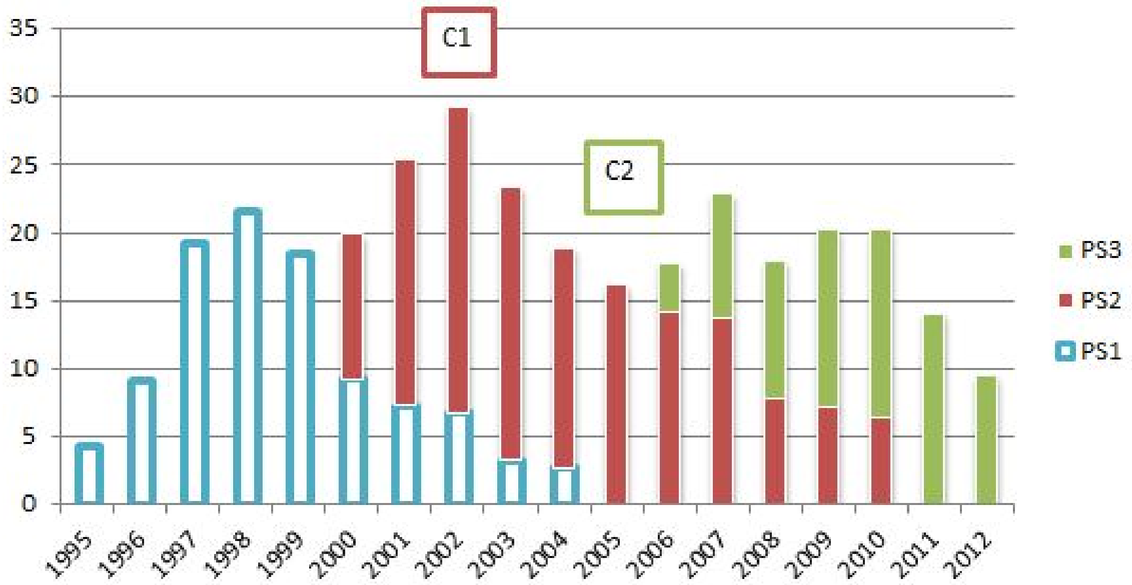

Figure 1.1: Playstation Shipments (millions units)

When Sony released the PS2, the PS1 sales started to decrease in favor of the new generation. PS2 increased its sales until Microsoft and Nintendo entered this generation in 2002. After that, PS2 sales lowered from around 20 million units to 16 million units. Then the PS3 appeared in 2006 and the PS2 sales started to decrease at a high growth, until Sony decided not to sell it anymore, six years after the start of the new generation.

The timing of the PS3 release was different when compared to other Playstations. Sony used to be a first mover or to respond quickly to the release of a new generation. This time, Microsoft Xbox360 was the first mover and it took Sony a year to react and introduce the Playstation 3. One might say that this delay caused the PS3 share of the generation's market (30%) to be lower than the PS2 generation's market (77%), probably due to the loss of reputation.

Another example is the Apple iPhone Sales history (as estimated by ASYMCO[6]) in Figure 1.2.

[6]See `http://www.asymco.com/2012/08/06/how-many`

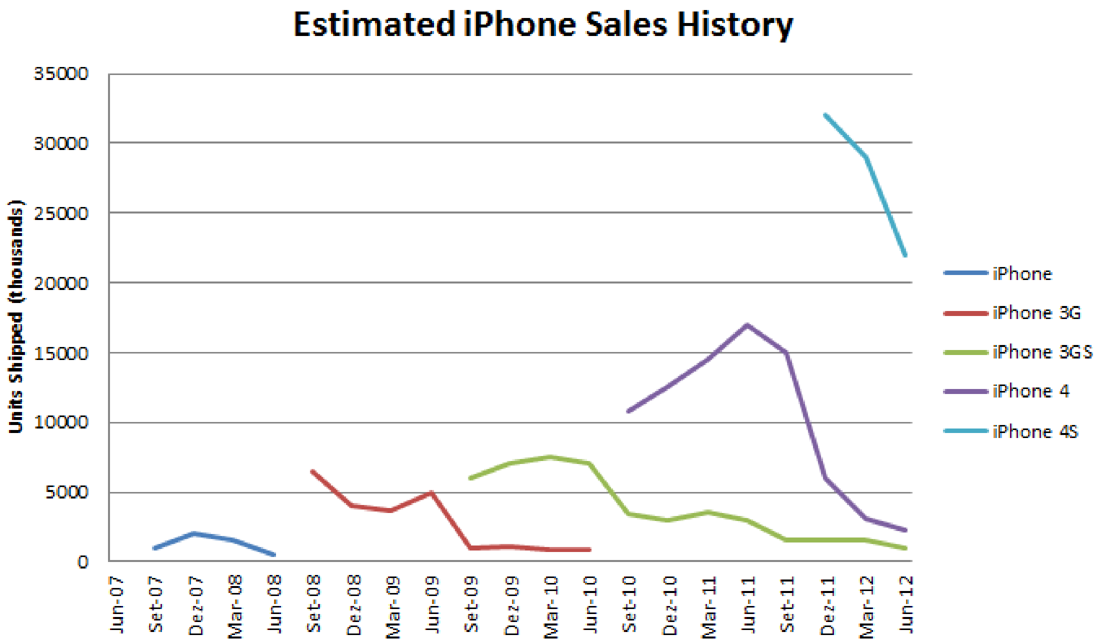

Figure 1.2: Estimated iPhone Sales History

As may be seen, when a new generation of the Apple iPhone enters the market, the previous one sees a big decrease in sales, but Apple chooses to continue to sell the older product at a lower price. This way Apple gains the segment of the market that is more demanding and does not care to pay a little more to have the new features, and gains the segment of consumers that want a lower price product.

The main purpose of this dissertation is to determine the optimal time to launch a new generation of a certain product, giving that this new product will affect the sales of the old one. Although the existing work about optimal timing to enter a market, in Real Options, may be true to some markets there are others that are left outside of these models, as most of these researches assume that the value of their projects will increase stochastically without limit, which does not happen in every situation. In some cases, such as the high-tech industry, there are always new products emerging, and the older products' value starts to see an inversion on its tendency to grow. Ignoring these markets is leaving outside big worldwide markets. Given that the product being sold by the company will see its sales starting to decrease after a new product enters the market, we believe that the cash-flows will increase only until a certain point (a certain cash-flow or moment in time), after which they will start to decrease. This point may be decided:

1. by the company alone, in which case the company is assumed to be a monop-

olist, which may be the case of companies whose customers are perfectly loyal and do not consider buying from another brand;

2. by a competitor that, for some reason, decided it was time to release a new technology. In this case the company faces competition in its market.

The innovation brought by this dissertation is met by the introduction of a scenario where the cash-flows grow stochastically until they stop to grow or start to decline, following the product's life-cycle, just as it happens in the high-tech market. When this happens the cash-flows of the product will grow at a different rate from before (eventually a negative one). Additionally the growth rate of the cash-flows of the new product may be greater than those of the first product as the market is now more mature and has a higher demand. Instead of valuing the option to enter the market as a call option we will valuate it as a put option, in which the company has the option to abandon the current product generation, exchanging it for the new generation. In other words the company will give up part of the cash-flows of a product in order to receive the full amount of cash-flows of a new product.

The reminder of this paper is as follows: the second chapter is a literature review about Real Options, the high-tech market and other subjects that contribute to this theme; the third chapter includes the development of the basic model, where we evaluate the optimal timing of a new product release, assuming the company has the control of the technological evolution (in this case the technological leap is inducted by the company which may decide when it is time for a new release); the forth chapter includes the development of the model where there is the possibility that the technology evolution may be inducted by the company's competitors (or other external entity) who will decide the perfect timing for a new product release(in this case the time of the technology leap is exogenous to the model); the fifth chapter includes a few practical and numerical examples of the model applied to the real world; the sixth chapter includes the conclusion of the paper, as well as some discussions.

Chapter 2

Literature Review

Having come a long way since they were firstly coined by Myers (1977), the Real Options theory is now seeing a sustainable growth as an area of academic research and as a tool for business and investment analysis. Nowadays the real options theory has become one of the most important fields in modern finances and its usage is expanding between managers and analysts.

Its usefulness also surpasses the companies and project's evaluation and it is being used as an auxiliary in determining investment strategies, appearing often related with the Games Theory, such as Fudenberg and Tirole (1985) study which analyzes the effects of preemption in games of timing, studying the adoption of a new technology. Some research carried in this area is based on the work of Dixit and Pindyck (1994). In this book the authors develop a model based on the stochastic value of the project evolving randomly, and derive a model where there is a leader-follower competition.

Huisman and Kort (1999) study how the investment under uncertainty combines with the investment under competition. When there is uncertainty the option value of waiting has to be considered by the company's investment timing decision, because when the company is investing it is also giving up the possibility of doing it later, with more information available. On the other hand, if the company does not invest quickly its competitors may do it, and the company may loose all of the project's value, or a part of it.

Nielsen (2002) expanded the knowledge in this area to situations where there is imperfect competition, with investments having positive externalities and situations in which a monopolist has multiple investment opportunities.

Tsekrekos (2003) explains the importance of investment strategies in Real options. Real Options, as opposed to financial options, may be held by a few investors at the same time and the exercising of one of the options affects the value of the rest of them. This feature justifies an approach that contemplates all of the option holders.

The author builds a model where there is a big threat of preemption and being first in the market may have advantages. These advantages are suitable of being, in part or as a whole, permanent.

Thus this author tries to approach the investment strategies combined with Real Options, in an attempt to find an equilibrium between the trade-off of exercising early and gaining the advantages of being a first-mover in the market or holding the option and waiting to see how the market evolves, thus decreasing the uncertainty.

Tsekrekos (2003) introduces a concept that may be applicable in a serious number of different markets. In the high-tech industry it is common to see the first mover gaining an advantage that is held throughout the whole lifetime of a generation and, sometimes, even on the transition to the next generation.

Paxson and Pinto (2003) approach the theme in a similar way to Tsekrekos (2003) but introduces an innovation: situations where the market share of a company may change due to the increase or decrease of consumers, just as happens in a birth/death process with a Poisson distribution.

The conclusion the authors have is that the value function of the Follower is less sensitive to market share changes and to the ratio arrivals/departures than the Leader's, until the cash-flows exceed the Follower's trigger. This trigger's value grows with the market share owned by the Leader, the ratio arrivals/departures and the cash-flows volatility. The Leader's value function is, still, unstable as the cash-flows get closer to the Follower's trigger.

Armada et al. (2011) continue the work of the previous authors, by considering the hypothesis of temporary or permanent advantages, but adds an innovation: in this case the model has the possibility of hidden competitors, which has a great impact on the decision to invest. In the high-tech industry there is a lot of different areas, and although some of the companies may sell certain types of goods but not others, it is common to see a company entering a new marketing and becoming a previously-hidden competitor (just as happened when Google entered the market of operating systems by introducing Android, or Microsoft entered the tablet hardware production with the Surface).

All of this models have in common the usage of a value of the project (or the company) evolving accordingly to a Geometric Brownian Motion. Bollen (1999) studies an option valuation framework where demand is governed by a product life cycle as opposed to using an expected growth of the value of the project. This is a different approach and very useful when valuing the introduction of goods, instead of entering a certain project. Rodrigues (2009) develops a model where demand can only grow up to a limit, which is determined by segment size and it can behave differently before and after the investment in each segment. So, the company may find it optimal to expand to new segments right after entering a previous segment or postpone it until the demand reaches the trigger.

Another work worth mentioning in this field of the Real Options is Ruiz-Aliseda and Wu (2012). These authors develop a model with the entry and exit decisions of companies that act in markets whose demand goes from growth to decline phases at uncertain times, introducing a process that captures this random evolution.

Daming et al. (2013) develop a real option game model to describe the impact of technological innovation on the market. These authors distinguish between incremental innovation ("sustainable or evolutionary innovation") and radical innovation ("sustainable or evolutionary innovation"), basing on Altshuller (1999) definition, and focus on the later, using a Poisson to describe the impact of this technological innovation on the market. The results of this is two Nash equilibriums whose critical points depends on the market response (the radical technological innovation capacity is greater when companies have a moderate market response to an enterprise product).

Several authors contributed to the definition of innovation, not only the meaning of the word, but also the concept behind it. One of the most cited is Schumpeter (1934), for it is believed that he was the first to propose an explicit definition for the word.

Reinganum (1989) studies the timing of innovation and examines combination of the expected benefits, the cost of research and development (R&D) and interactions among competing firms. This author analysis the incentives for individual companies to invest in R&D extent based on the rivalry and appropriability interactions between the companies acting in the market, as well as the effects of licensing (primarily fixed-fee contracts) the technology discovered and the diffusion of innovation over time.

On the research about innovation acceptance, Chaney et al. (1991) study how the introduction of a new product affects the market value of the companies, using a market-based analysis, concluding that there is a small increase over a short period of time, but the impact of an introduction varies negatively with the magnitude of the firm's systematic risk and negatively with the number of announcements made over the decade. Also the market reaction to the announcement seems to be related to the number of products in the announcement (multiple products seem to induce a larger effect) and the degree of innovation brought by them.

Chou and Yang (2011) examine the interaction between the strategic orientation of high-tech companies, namely their innovation orientation, two types of market orientations (responsive and proactive), and new product performance. They conclude that new product performance, when derived from the interaction between innovation orientation and responsive market orientation show that the interaction effect is contributory to firm performance until an optimal level is reached, and then the effect becomes adverse thereafter. On the other hand, when new product performance is derived from innovation orientation and proactive market orientation the interaction effect is detrimental to firm performance until a threshold level is reached and then the effect becomes contributory thereafter.

The introduction of a new product must follow some strategies because, as said before: in this business the market has high uncertainty and growth, aggressive competition with the probability of entrance of hidden competitors, sometimes two high-tech industries have two different technologies that are competing for one market, and one is a substitute of the other. As Zahra and Bogner said: "Technology, the sum of a firm's knowledge and skills, determine the ability of new ventures to offer the products (services), gain market acceptance, survive, and achieve financial success"(Zahra and Bogner 2000, p.136). If the company releases its product too soon it will affect the sales of the older product and will allow the competition to either replicate it at a lower price or have a more technologically-advanced product. If the company releases the product too late it will allow the competition to enter the market and affect the company's reputation as well as secure the advantages of being a first mover.

Takeuchi and Nonaka (1986) address the importance of strategies when releasing a new product. Due to the fast-pacing changes in consumers habits in a competitive world of commercial new product development, companies are emphasizing the new products as a source of new sales and profits, as the old products represent less and less of the market share. According to this author more and more consumers tend to choose the new products, instead of the old ones, in contrast to what happened in the past.

The degree of adoption of a new product will depend on the consumers' perceived value of it as well as its cost. If the consumers find it to have a big improvement of value over its predecessor they will buy it, otherwise they will buy the old product, taking advantage of the possible price drop, or not purchase any. There is also to consider the complementarity between that product and other products that the consumer may have, as the tendency to adopt the new product increases with its compatibility with other products already held by the consumer.

The case of complementary technology in a world of uncertainty is studied by Azevedo and Paxson (2009). These authors find analytical or quasi-analytical solutions for the leader and the follower value functions and their respective investment thresholds, in a world of uncertainty, competition and technological complementarity. In their model, the investment game firms have two technologies available, whose functions complement each other, and the option to adopt both technologies at the same time or at different times, in a context where the evolution of their gains is uncertain. Their results show that given the uncertainty about revenues and the price of the two technologies, it might be optimal for the leader and the follower to adopt the two technologies asynchronously (first, the technology whose price is decreasing at a lower rate and then the technology whose price is decreasing more rapidly). It is common to see some complementarity between different products in this industry. It is the case of the media holders and media readers, the computer and modems, the game consoles and joysticks. It is even common to see complementarity between generations of products: Nintendo's Wii games and accessories are compatible with its new console (Nintendo Wii U) and Apple iPhone 4 cases and cables were compatible with the Apple iPhone 4S.

Rubera et al. (2012) identify the key dynamics that contribute to successful new product rollouts (significant product release, often accompanied by a strong marketing campaign to generate a large amount of consumer hype[1]) within a region: the type of innovation and the cultural and economic factors. A longer regional rollout strategy is more desirable for technological innovations because new technology may have a steep learning curve and may need some infrastructures (such as an increase of the speed of the internet). The risk avoidance culture of a country is also important as a longer regional rollout strategy for technological innovations achieve greater market share in countries with high uncertainty avoidance. On the other hand a short rollout may benefit the company when it is thought that the product will provide, or at least maintain, high levels of status within an individual's peer group and in markets with higher economic openness. As economic openness will make it easier for market entrance it will also increase competition as easier market

[1]http://www.investopedia.com/terms/r/rollout.asp

entry applies to all other new entrants, so the company will benefit from gaining the pioneer advantages.

The perceived economic value of high-tech consumer products is studied by Munnukka and Järvi (2011). More precisely these authors study the influence of customer-value hierarchy factors on consumers value perceptions of high-tech products. This study is important to understand the degree of adoption of a new product over the old one, which may determine how the market is split between the two products. They identify five categories of factors that could influence the perceived value of a high-tech product, and test each one of them as hypothesis:

1. It's ability to fulfill the costumer's latent subjective goals (such as ease of mind, increase in self-esteem, enjoyable and problem-free use experience, and overall effectiveness);

2. The benefits perceived by the costumer (no hassle, reliability, ease of use, time saving, desired visual view, independence of time, availability, high quality/cost ratio, and so on);

3. The product's direct attributes (such as layout of instruments, size, smooth shift, design, frequency of repair, low price, product quality, display, keyboard);

4. Buyers needs and the opinion of others (how the product is perceived by others in the buyers social network affects the perceived economic value of the purchased high-tech product);

5. The extent to which the purchased high-tech product is in use in the buyers social network.

These authors conclude that the first hypothesis obtained support but the result suggests a weak model fit. The second and third category have important factors (the direct attributes is the most important one). The forth category is only partly supported and taking into consideration others opinions was found to reduce the product's perceived value. The fifth category seems to be fully supported with the extent to which the product had diffused into the respondents social network having a positive effect on the consumer's perception of economic value. This discrepancy (between category four and five) might be explained by consumers tendency to rationalize their buying decisions through personal needs and wants, while social factors operate in the background.

Lee et al. (2012) also conduct a research on the factors that influence the consumer's perception of the product's attributes to be an object of interest, which will influence the diffusion of new high-tech products in the market. These authors examine the influence of hierarchical product attributes on actualized innovativeness, and base their study on the relationship between product attributes and actualized innovativeness and in identifying hierarchical patterns in the relationship. The conclusion of the study is that the unexpected and non-essential (tertiary) attributes have a stronger impact than the expected but non-essential (secondary) attributes and the expected and essential (primary) ones.

In our model we consider that the product's cash-flows evolve stochastically according to a Geometric Brownian Motion mixed with a life-cycle (the cash-flows increase until a certain value and then start to decrease). Also, there is hidden competition, and when a competitor enters the market the company may not loose half of its cash-flows (sharing the market in equal parts).

After exercising the option the company will have two products sharing the market in different parts, whose value will be dependent on the perceived value of the new product as well as its capability to have a successful rollout.

After seeing how the existing work influenced our model we will proceed to our model.

Chapter 3

The decision to launch a new generation model under a monopolistic setting

In this section we will introduce a model where the company has the control of the technology leap, being able to determine when the next generation starts and, therefore, the competition (or the threat of it) does not exist. This is the case when the product is a new-born good, and the company launching it has the know-how to do it and has the lead on research and development. This often occurs when a new good is released, which creates a new market, and it takes some time before competitors arise.

Assume that the company has one product in a market that meets the assumptions mentioned above, and receives a certain amount of cash-flows which we will denominate as x. This x evolves following a Geometric Brownian Motion:

$$dx = \alpha x dt + \sigma x dz \tag{3.1}$$

where α represents the risk-neutral expected growth rate of the cash-flows. σ is the volatility and, for convenience, we assume that the volatility of the cash-flows is the same independently from the generation available in the market. Finally dz is the increment of a standard Wiener process. As the equation shows, one may know the value of the current cash-flows but its future values are lognormally distributed with a linear growing over the time variance.

The model we developed is a two period model:

- The first period where the company has one product to sale. This is the continuation region, as it is not yet optimal for the company to launch the product at that moment. We will later refer to it as the Previous Generation (P) moment;

- The second moment where the company releases the new product, as it is optimal to invest (stopping region). We will later refer to this moment as the New Generation (N) moment.

This market is assumed to be complete, and it is possible to replicate this company's options with financial assets, thereby the required rate of return is the risk-free rate of return, denominated as r (and $r > \alpha$). This means that the company's value, in the Previous Generation period, according to the Net Present Value (NPV) will be:

$$\int_0^\infty xe^{-(r-\alpha)t}dt = \frac{x}{r-\alpha} \tag{3.2}$$

At some point in time the company will introduce a new and upgraded version of its product. This upgraded version suits more costumers and may expand the market. The cost of producing the first product will now be lower, and the company may choose to sell it with a lower price, reaching to more consumers. Sometimes companies choose the introduction of a new product to introduce the old product into new markets with lower purchase power, trying to increase (or at least maintain) its sales. With two products now being sold it is likely that the market will expand, because of the complementary products. An example of this is the DVD players' market, as mentioned before, or the smartphone's market. With the first generation of smartphones being sold at a lower price, the number of devices sold will, most likely, increase because new consumer segments will be reached. With the increase on the number of devices sold the number of available applications will also increase. This will make the smartphones more desirable, so the market will expand.

The company's cash-flows will now have two sources: its first product and its new product. Since the new is an improvement over the old product it is likely to see a cut-down on the old product's sales. The immediate decrease in sales will be represented by $\phi \in [0, 1]$, depending on the perception of the increased value that the new product has over its predecessor. It is expected that the new product will have some new features when compared to the old one, and will be released in a more mature market (since the old one had already made its way into the market), thus it is expected that sales will have a boost. The cash-flows of the new product at the starting point of its sales, as expected by the company are y. This value may also be re-estimated by the company if it feels like the market has somehow changed and the estimations may have to be re-thought.

Since there is a new and improved product on the market, the old one will have a new rate of growth α^P (that can be positive or negative). The new products growth rate will be α^N.

The cash-flows from the old product, after the release of the new one turns to be:

$$\int_0^{\infty} x(1-\phi)e^{-(r-\alpha^P)t}dt \; = \frac{x(1-\phi)}{r-\alpha^P} \tag{3.3}$$

Notice that where before was x is now $(1-\phi)x$, which captures of the losses in sales induced by the existence of a new generation product. One may assume that the two new product will not be good enough to surpass the old one and assign 0 to ϕ. The model also contemplates the possibility that the old product will disappear and, in that case, ϕ would be equal to one. Also notice that α is now α^P because it is now a different generation, and the old product's sales will evolve differently from the past. Again, there is the possibility that α^P equals α. The model was developed to be suitable to a large variety of markets and conditions.

The cash-flows of the new product will be:

$$\int_0^{\infty} ye^{-(r-\alpha^N)t}dt \; = \frac{y}{r-\alpha^N} \tag{3.4}$$

Again, y represents the cash-flows of the new product at the starting point of its sales, as expected by the company. Remember that those are estimated by the company, and the estimations may have to change overtime in order to accommodate possible changes in the market. α^N is the expected perpetual growth rate of the cash-flows produced by the new product (y).

So, when the company has only one product, its entirely cash-flows will come from that product and, since there is no competition, the company could stay there forever. But the knowledge that the release of a second product will boost the market, probably increasing its cash-flows, makes the company wonder about the option to launch a new product. To exercise this option (launching of a new product) the company will have to pay K (here K may be seen as all of the costs of commercializing a product). This new product will cannibalize the older one (partially or fully) and the company will see its cash-flows as coming from two different products. In this case the boost in the market will only be felt in the new generation of goods, and the cash-flows of the two generations of goods will evolve differently from each other.

Following Dixit and Pindyck (1994) in the continuation region (where the values of x have not yet reached it's trigger value and, therefore, it is not optimal to launch a new generation), and keeping in mind that the company is already active in the market we obtain:

$$rFdt = E(dF) + xdt \tag{3.5}$$

where xdt corresponds to the instantaneous cash-flows of the current generation technology.

Under risk uncertainty, the total expected return on the investment opportunity is $rFdt$, which is equal to the expected rate of capital appreciation.

Using Ito's Lemma to expand dF the equation becomes:

$$dF = F'(x)dx + \frac{1}{2}F''(x)(dx)^2 \tag{3.6}$$

Substituting Equation (3.5) for dX and given that $E(dz) = 0$:

$$E(dF) = \alpha xF'(x)dt + \frac{1}{2}\sigma x^2 F''(x)dt \tag{3.7}$$

The ordinary differential equation will then become:

$$\frac{1}{2}\sigma^2 x^2 F''(x) + \alpha F'(x) - rF(x) + x = 0 \tag{3.8}$$

The general solution to this equation will be:

$$F(x) = A_1 x^{\beta_1} + A_2 x^{\beta_2} + \frac{x}{(r-\alpha)} \tag{3.9}$$

In addition, $F(x)$ will have to satisfy the following boundary conditions:

$$\lim_{x\to+\infty}\left(F(x)-\frac{x}{r-\alpha}\right)=0 \tag{3.10}$$

$$\lim_{x\to x_F^*}F(x)=\frac{x_F^*(1-\phi)}{r-\alpha^P}+\frac{y}{r-\alpha^N}-K \tag{3.11}$$

$$\lim_{x\to x_F^*}F'(x)=\frac{1-\phi}{r-\alpha^P} \tag{3.12}$$

The first condition (3.10) ensures that the option component of the value function tends to zero as x tends to infinity. This means that option to launch the new generation product will be worthless when the cash flows of the old product becomes infinity large. In other words the higher the present values of the future cash-flows the lower will be the value of the option because the company will have less incentive to release a new product and sacrifice part of the cash-flows of the old product.

The second condition (3.11) is the value-matching condition. When the company decides to invest, it will receive the present value of the cash-flows originated by the old product and the present value of the cash-flows that come from selling the new one. The company will have to pay K in order to exercise the option, which is, in this case, all of the costs required to release the new product. Notice that the option is exercised when x hits x_F^*, the so called trigger value. In our model x_F^* corresponds to the New Generation moment.

The third condition (3.12) is the smooth-pasting condition, which assures that the function is continuously differentiable along x.

After considering the boundary condition of equation (3.10) the solution for $F(x)$ comes:

$$F(x)=A_2x^{\beta_2}+\frac{x}{(r-\alpha)} \tag{3.13}$$

Solving equation (fFsemi) according to the boundary condition of equation (3.11) we obtain the value of A_2:

$$A_2=\left[\frac{x_F^*(1-\phi)}{r-\alpha^P}+\frac{y}{r-\alpha^N}-\frac{x_F^*}{r-\alpha}-K\right]\left(\frac{x}{x_F^*}\right)^{\beta_2} \tag{3.14}$$

Replacing equation (3.14) in equation (3.13) we define obtain the complete solution:

$$F(x) = \begin{cases} \left[\dfrac{x_F^*(1-\phi)}{r-\alpha^P} + \dfrac{y}{r-\alpha^N} - \dfrac{x_F^*}{r-\alpha} - K\right]\left(\dfrac{x}{x_F^*}\right)^{\beta_2} + \dfrac{x}{r-\alpha} & \text{for } x \geq x_F^* \\ \dfrac{x(1-\phi)}{r-\alpha^P} + \dfrac{y}{r-\alpha^N} - K & \text{for } x < x_F^* \end{cases} \tag{3.15}$$

The first branch of the equation (the upper one) represents the value that the company receives for being in the market with its first product added with the value of the option to release a new one. The company will likely decrease the older product's sales in exchange for having bigger sales in the new product. After the release of the new generation both products will be in the market, and the company's cash-flows will come from both products. Nevertheless the model is flexible to contemplate the scenario where the sales of the old product go directly to zero.

The second branch (lower one) represents the value that the company will receive after the release of the new generation, net of the exercise price.

The trigger (the value from which the company will exercise the option to release a new product) is:

$$x_F^* = \frac{\beta_2}{(\beta_2 - 1)} \frac{K - \frac{y}{r-\alpha^N}}{\frac{1-\phi}{r-\alpha^P} - \frac{1}{r-\alpha}} \tag{3.16}$$

where β_2 is:

$$\beta_2 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} \tag{3.17}$$

Notice how two different situations may emerge from equation (3.16):

- $K < \frac{y}{r-\alpha^N}$. This is the case of the positive NPV, which is the most common situation., since K is just an incremental investment (the facilities, the equipments, and all the business structure already exists). For keeping the economic meaning $\frac{1-\phi}{r-\alpha^P} - \frac{1}{r-\alpha} < 0$. If $\alpha^P \leq \alpha$ any positive ϕ reveals adequacy (remember that $\phi \in [0,1]$). If $\alpha^P > \alpha$ (but in any case lower than r), than $\phi \in [\frac{\alpha^P-\alpha}{r-\alpha}, 1]$.

- $K > \frac{y}{r-\alpha^N}$. This is a negative NPV project, which should be an uncommon situation when the investments expands significantly the old structure. For being acceptable the old product's cash-flows should benefit also from this instrument. In this case the economic meaning is guaranteed when $\frac{1-\phi}{r-\alpha^P} - \frac{1}{r-\alpha} > 0$. This is only possible when $\alpha^P > \alpha$.[1] However, a restriction for ϕ is needed, depending upon the level of $\alpha^P : \phi \in [0, \frac{\alpha^P - \alpha}{r-\alpha}]$ when $\alpha^P > \alpha$.

[1]In fact, if $\alpha^P \leq \alpha$ that would require a negative ϕ, which is impossible.

Chapter 4

The decision to launch a new generation product under competition

In this section we extend the previous model by introducing competition in the market. In this model the timing for introducing a new high-tech product is not totally controlled by the company, as another rival firm may take the first step and release a product with the new technology. When someone 8either the company or a rival firm) releases a product with the new technology a new generation begins. As a result of this, when the company postpones the start of a new generation it is facing the risk of someone starting it first. If this happens the company will have to settle for being a second mover, with negative repercussions.

In our model then, negative repercussions come in terms of reputation, as the market will stop seeing the company as a pioneer, or as a leading innovative company. This loss of reputation will influence the company's cash-flows. The loss in the cash-flows will affect the old product and the new one. There is the possibility that the loss in reputation is higher in the new product as compared to the old one, because consumers seem to distinguish very well between generations, and so we choose to consider it two different variables, but one might choose to consider it the same variable and to consider the same value for both.

So in this model, if the company invests there are two possible roots:

- The company successfully enters the new generation, and in this generation it will received the cash-flows without the loss of reputation effect. In this case the company will receive the cash-flows accordingly to the previous model where the company had the control of the technology leap;

- The company fails to start a new generation and, because of its lost of reputation, it will have to receive lower cash-flows.

If the second root happens there will be three moments of time:

1. When the company is acting only on a generation, having one product in its portfolio, receiving x cash-flows and having the option to enter a new generation. The company may be the first mover if it enters before the competition, but there is a risk of being preempted if the competition moves first. the entrance of a rival firm is modeled as a Poisson jump with an intensity λ;

2. When a new product, from a competitor, enters the market with a new, and improved, technology, it affects the company's reputation as well as its cash-flows, which will now decrease to $x(1-h_1)$. The company still has the option to enter the new generation market, but now it knows that it will only be possible as a second mover;

3. When the company releases a new good, to compete with its rival product. The company lost reputation will affect not only the old product but also the new one, and its cash-flows will be, respectively, $(1-\phi)x(1-h_1)$ (remember that $(1-\phi)$ is the loss in the company's cash-flows due to the release of a new product) and $y(1-h_2)$ (remember that y is the starting point of the new product's cash-flows).

Remember, also, that the loss of reputation may not affect both products in the same way. The first one will loose h_1 of the cash-flows, whilst the new one will loose h_2 of its cash-flows. This is due to the difference between the perception of the consumers before and after the release of the new product. Keeping this in mind three solutions may be possible:

- $h_1 > h_2$, if the new product succeeds to change the consumers perception of the company, making them believe that the new product is good enough to choose over the competition, and even though the company was not pioneer introducing the new technology, it still released a product with interesting specs and configurations;

- $h_1 = h_2$, if the new product does not impress the consumers, and their negative view of the company being a follower did not change. If this happens, the loss of reputation will affect both products by the same amount;

- $h_1 < h_2$, if the new product disappoints the consumers. The company had already lost reputation due to being late in the market, and the new product failed to meet the consumers expectations, lowering the company's reputation concerning the new product.

So, in the beginning there is a company, acting in the market and receiving x cash-flows, but facing the possibility that a competitor releases a new product, which will lower the company's cash-flows, and leaving it with the option to enter that generation. As usual the solution must be solved backwards, starting with the scenario where the rival has already released its product, and it is up to the company to choose whether or not to invest, launching a new product as well, and when to do it.

After the entrance of the rival firm, the old product is worth:

$$\int_0^\infty x(1-h_1)e^{-(r-\alpha)t}dt \;=\frac{x(1-h_1)}{r-\alpha} \tag{4.1}$$

Just as happened in the previous model, the company may introduce a new upgraded version of its product, which may expand the market. The company's cash-flows will have two sources: its first product and its new product. The first part of the cash-flows will be $x(1-\phi)$, while the second part will be (y).

Since there is a new and improved product on the market, the old one will have a new rate of growth α^P (it will be a positive or negative one, depending on the company's strategy of releasing it or not in another countries with less consumption power). The new products rate of growth will be α^N. The company's value will be the sum of its assets in place with the option to release a new product. The latteris given by $H(x)$.

The new differential equation comes:

$$\frac{1}{2}\sigma^2x^2H''(x)+\alpha H'(x)-rH(x)+x(1-h_1)=0 \tag{4.2}$$

Following the development of the equation showed in the section before, the solution to this equation will be:

$$H(x) = E_1 x^{\beta_1} + E_2 x^{\beta_2} + \frac{x(1-h_1)}{r-\alpha} \tag{4.3}$$

In addition $H(x)$ will have to satisfy the following boundary conditions:

$$\lim_{x \to +\infty} \left(H(x) - \frac{x(1-h_1)}{r-\alpha} \right) = 0 \tag{4.4}$$

$$\lim_{x \to x_H^*} H(x) = \frac{(1-\phi)x_H^*(1-h_1)}{r-\alpha^P} + \frac{y(1-h_2)}{r-\alpha^N} - K \tag{4.5}$$

$$\lim_{x \to x_H^*} H'(x \frac{(1-\phi)(1-h_1)}{r-\alpha^P} \tag{4.6}$$

Once again, the first condition (4.4) ensures that the option component of the value function tends to zero as x tends to infinity. This means that option to launch the new generation product will be worthless when the cash flows of the old product becomes infinity large.

The second condition (4.5) is the value-matching condition. If the company decides to invest, it will receive the present value of the cash-flows originated by the old product and the present value of the cash-flows that come from selling the new product (remember that this time the value of the product may be lower because of being a second mover). The parameter K is the cost to exercise the option, which is, in this case, all of the costs required to release the new product (we assume that K does not depend upon being a first or second mover). The company should launch its new generation when x hits x_H^* means the values of x for which it is optimal to invest and release a new product, because this values are in the stopping region (New Generation moment).

The third condition (4.6) is the smooth-pasting condition, which assures that the function is continuously differentiable along x.

After considering the boundary conditions the solution comes:

$$H(x) = \begin{cases} \left[\frac{(1-\phi)x_H^*(1-h_1)}{r-\alpha^P} + \frac{y(1-h_2)}{r-\alpha^N} - \frac{x_H^*(1-h_1)}{r-\alpha} - K \right] \left(\frac{x}{x_H^*} \right)^{\beta_2} + \\ + \frac{x(1-h_1)}{r-\alpha} & \text{for } x \geq x_H^* \\ \\ \frac{(1-\phi)x(1-h_1)}{r-\alpha^P} + \frac{y(1-h_2)}{r-\alpha^N} - K & \text{for } x < x_H^* \end{cases} \tag{4.7}$$

The first branch of the equation (the upper one) represents the value that the company receives for being in the market with its first product, after the competitor has entered the market, added with the value of the option to release its new product. The company will likely decrease the older product's sales in exchange for having bigger sales in the new product. After the launch of the new generation, both products may be in the market, each one contributing with its cash-flows to the company. Nevertheless this model contemplates the scenario where the sales of the old product go directly to zero and any scenario between the new product having part of the market or the total of it.

The second branch (lower one) represents the value that the company will receive after the release of the new generation, net of the exercise price.

Notice that when there is no reputation costs (h_1=h_2=0) the value function of $H(x)$ and the trigger x^*_H become, respectivelly, $F(x)$ and x^*_F. This means that, without reputation damage, the company acts as a monopolist.

The trigger (the value from which the company will exercise the option to release a new product) will be:

$$x^*_H = \frac{\beta_2}{\beta_2 - 1} \frac{K - \frac{y(1-h_2)}{r-\alpha^N}}{\frac{(1-h_1)(1-\phi)}{r-\alpha^P} - \frac{1-h_1}{r-\alpha}} \tag{4.8}$$

Having the solution for the moment when the rival has already entered the market, we will now study the moment where there is the possibility of a competitor entering the market.

The company is acting in the market, receiving a certain amount of cash-flows x, and having the option to release a new product. At the same time, there is the possibility that a competitor moves firstly into the market starting that generation.

If the company is the first mover it will receive its cash-flows, $\frac{(1-\phi)x}{r-\alpha^P} + \frac{y}{r-\alpha^N}$.

On the other hand if the rival moves first the company will stop receiving x and will be receiving $x(1-h_1)$ for the reasons mentioned before. The company will have lost its option to be a first mover, receiving $\frac{(1-\phi)x}{r-\alpha^P} + \frac{y}{r-\alpha^N}$ and will have the option to be a second mover and receive $\frac{(1-\phi)x(1-h_1)}{r-\alpha^P} + \frac{y(1-h_2)}{r-\alpha^N}$.

Notice how the company goes from having the option $F(x)$ to having the option $H(x)$. Hence the company, at the starting point, will have the option $G(x)$, which may turn out to be an option $F(x)$ with some probability of becoming an option $H(x)$. The possibility of this happening is given by λ, which will capture the probability of the competitor releasing a new product and becoming a first mover.

So, the differential equation will be:

$$\frac{1}{2}\sigma^2 x^2 G''(x) + \alpha G'(x) - rG(x) + x + \lambda(H(x) - G(x)) = 0 \tag{4.9}$$

As usual $G(x)$ must satisfy a set of boundary conditions[1]:

$$\lim_{x \to +\infty} \left(G(x) - \frac{x}{r-\alpha} \right) = 0 \tag{4.10}$$

$$\lim_{x \to x_G^*} g(x) = \frac{x_G^*(1-\phi)}{r-\alpha^P} + \frac{y}{r-\alpha^N} - K \tag{4.11}$$

$$\lim_{x \to x_G^*} G'(x) = \frac{1-\phi}{r-\alpha^P} \tag{4.12}$$

After considering the boundary condition (4.10), the solution comes:

$$G(x) = C_2 x^{\gamma_2} + \frac{h_1 x}{r-\alpha-\lambda} + H(x) \tag{4.13}$$

Solving equation (4.13) according to the boundary condition of equation (4.11) we obtain the value of C_2:

$$C_2 = \left[\frac{(1-\phi)x_G^*}{r-\alpha^P} + \frac{y}{r-\alpha^N} - \frac{h_1 x_G^*}{r-\alpha-\lambda} - H(x_G^*) - K \right] \left(\frac{1}{x_G^*} \right)^{\gamma_2} \tag{4.14}$$

By replacing equation (4.14) in equation (4.13) we obtain the complete solution:

$$G(x) = \begin{cases} \left[\frac{(1-\phi)x_G^*}{r-\alpha^P} + \frac{y}{r-\alpha^N} - \frac{h_1 x_G^*}{r-\alpha-\lambda} - H(x_G^*) - K \right] \left(\frac{x}{x_G^*} \right)^{\gamma_2} + & \\ + \frac{h_1 x}{r-\alpha-\lambda} + H(x) & \text{for } x \geq x_G^* \\ & \\ \frac{(1-\phi)x}{r-\alpha^P} + \frac{y}{r-\alpha^N} - K & \text{for } x < x_H^* \end{cases} \tag{4.15}$$

This time the trigger value does not have an analytical solution. In order to find it one most solve numerically the following equation:

$$\gamma C_2 {x_G^*}^{\gamma_2} + \frac{h_1 x_G^*}{r-\alpha+\lambda} + H'(x_G^*) x_G^* = \frac{(1-\sigma)x_G^*}{r-\alpha^P} \tag{4.16}$$

[1]The economic interpretation of the boundary conditions is similar to the ones represented previously.

where γ_2 is the following equation:

$$\gamma_2 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{r+\lambda}{\sigma^2}} \tag{4.17}$$

If the probability of a rival entering the market (λ) or the effects of this entrance in the reputation of the company (h_1 and h_2) were null $G(x)$ would become $F(x)$ (see chapter 3).

After developing the models we will next apply them to real-world situations.

Chapter 5

The case of the Sony Playstation video-games business

In this chapter we will apply the model to a real-world situation. For this purpose we collected some data about the Sony Playstation sales[1].

We will present three different situations:

- One where the company introduces its product earlier than its rivals. This is the case of the Playstation 1 transition to the Playstation 2 (PS1 to PS2);
- One where the company introduces its product after the competition, loosing reputation. This is the case of the Playstation 2 transition to the Playstation 3 (PS2 to PS3);
- One where the company there is the possibility of a rival entering the market. this is the case of the Playstation 2 transition to the Playstation 3 before the Microsoft Xbox 360 was released.

In the final section of this chapter we will present a comparative statics and sensitive analysis.

Notice, however that this exercise is just for demonstration purposes. We do not have enough data, and do not intent, to make a final assessment of the optimal timing for this company to introduce a next generation product. We will have some assumptions in order to keep the application simple.

The reason we chose the video game industry is because we feel it illustrates well enough the high-tech market.

[1]From vgsales.wikia.com and Sony's financial reports

It is easy to distinguish between generations because they seem to last for five to seven years and usually there is something in common between the products available for that generation (for example, the forth generation is known as the 16-bit era because of the hardware used). It is important to know the perfect timing to release a product, as the Sony Playstation benefited from being launched before the Sega Saturn, but the Sony Playstation 3 suffered from being sold after the Xbox 360. It is a market where the old product continues to be sold (Sony continues to sell its old generation products five years after the release of the new generation), which is good to see how the model fits reality. Being a high-tech market there is always high uncertainty as new technologies are constantly being discovered and new ways of competition (nowadays it seems that smartphones and social network mini-games are stealing consumers from home video games), with hidden competitors (Microsoft only entered the market in 2002 with the first Xbox). Also, there seems to be an effect on the sales of the old generation when the new generation starts.

We start by taking a look at Sony Playstation's sales per fiscal year (ending in March) in the Figure below:

Playstation (shipments millions of units)	PS1	PS2	PS3	Entrance of Competitors
1995	4,3			Sega Saturn (PS1)
1996	9,2			Nintendo 64 (PS1)
1997	19,37			
1998	21,6			
1999	18,5	1,41		
2000	9,31	9,2		
2001	7,4	18,07		
2002	6,78	22,52		Xbox and Gamecube (PS2)
2003	3,31	20,1		
2004	2,77	16,17		
2005		16,22		Xbox 360 (PS3)
2006		14,2	3,6	Wii (PS3)
2007		13,7	9,2	
2008		7,91	10,06	
2009		7,3	13	
2010		6,4	13,89	
2011			14,11	
2012			9,54	Wii U (PS4)

Figure 5.1: Sony Playstation sales per fiscal year

In the first column we can see the fiscal year to which the sales refer. PS1, PS2 and PS3 refer to the first, second and third generations of Sony Playstation's consoles. On the fifth column we can see the name of Sony's competitors, the year when they release their video game system and in which generation it belonged.

In order to know the cash-flows provided by each console we must assume that they only come from the sales of the consoles, ignoring the software and accessories sales (as we do not have enough information for that). The prices of the consoles are not static, and tend to lower throughout time. Given that we do not have the sales per month, we assume that when there is a price drop it affects the prices of all the consoles sold that year. So, imagining that Sony lowered the price of one console in the middle of a year, we will assume that price to all the consoles sold that year.

Since we do not have the production costs we will assume the cash-flows to be equal to the operating incomes. We will assume the operating incomes to be a fixed percentage (the 2010 values) of the sales. This means that we assume the net cash-flows of a year to be "sales (in dollars)" times the 2010 "Operating Income/Sales 2010" ratio for the gaming division and assumed it to be constant.

Playstation sales (in million of dollars)	PS1 Units*Price	PS1 Cash-Flows	Growth	PS2 Units*Price	PS2 Cash-Flows	Growth	PS3 Units*Price	PS3 Cash-Flows	Growth	Entrance of Competitors
1995	1.290	72								Sega Saturn
1996	2.760	155	1,14							Nintendo 64
1997	3.874	217	0,40							
1998	3.240	181	(0,16)							
1999	2.387	134	(0,26)							
2000	922	52	(0,61)	3.183	178					
2001	733	41	(0,21)	5.421	304	0,70				
2002	332	19	(0,55)	6.756	378	0,25				Xbox and Gamecube
2003	162	9	(0,51)	4.020	225	(0,40)				
2004	136	8	(0,16)	2.894	162	(0,28)				
2005				2.903	163	0,00				Xbox 360
2006				2.542	142	(0,12)	1.980	111		Wii
2007				1.767	99	(0,30)	5.060	283	1,56	
2008				1.020	57	(0,42)	4.527	254	(0,11)	
2009				942	53	(0,08)	5.850	328	0,29	
2010				634	35	(0,33)	4.167	233	(0,29)	
2011				-			4.233	237	0,02	
2012				-			1.908	107	(0,55)	Wii U

Figure 5.2: Sony Playstation total sales per unit

As the risk-free we used the 10 years Japanese Government bonds yields of August 1994 to August 1995 (4%), as the PS1 was released in 1995, Sony is a Japanese company and Japan is the world's biggest video-game markets.

In order to know the value of the cash-flows growth, or drift, (α) we used the cash-flows shown before. But since we are working in a risk-free environment, we have to find the risk-neutral drift (α^*)[2]. The risk premium was obtained using the CAPM model with a β and a premium for the risk given of the entertainment tech industry by Damodaran (7%) [3], a risk-free rate as mentioned before, and Sony's financial reports to know the debt-to-equity ratio and the tax rate.

According to Sony's financial reports, the value of the investment, K is 24.57 million euros.

The value of ϕ was considered to be:

- 0.614 in the first example (because when Sony released the PS2, the sales of the PS1 lowered 61.4%);
- 0.3 in the second and third examples (the consumers do not see an increase in quality from the PS2 to the PS3 as high as it was from the PS1 to the PS2 - as may be seen from year 2006 to 2007)

As a simplification for the project's volatility (σ) we used Sony's share's daily returns volatility:

- in the first example, from 1995 until 2000 (year of release of the PS2). The value of σ is, then, 0.3;
- in the second and third example, since the PS3 came after the PS2 (which was released in 2000), and was released in 2006 we considered only the period between 2000 and 2006, as Sony was evaluating when to release the new generation during that period. So, σ is 0.369.

5.1 PS1 to PS2

Sony Playstation was a huge success for the company, as the console was one of the most remarkable consoles of all time, being the most sold one during that generation.

Sony first introduced Playstation (or PS1) during the year 1995, almost at the same time as one big competitor (Sega Saturn), and a few moments before other major competitor (Nintendo 64). With these products being released with few

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[2]Since $\mu - \alpha = \delta$ and $r - \alpha^* = \delta$ and considering that $\mu = r + RP$ where RP stands for the Risk Premium (CAPM), it comes: $r + RP - \alpha = r - \alpha^*$, and so: $\alpha^* = \alpha - RP$ where α^* is the risk-neutral drift and α is the risk-adjusted drift.

[3]http://pages.stern.nyu.edu/ adamodar/ on 4^{th} of May, 2013

months apart, Sony and its competitors were able to put all the cards in the table at once, and fight for the consumers preference.

In this first example we will consider that Sony was the Leader of the market, and that the PS1 was so successful that the competition could not danger Sony reputation on the market when the company decided to release the PS2, so the model fits the case where the company controls the technology leap, acting as a monopolist.

In Figure 5.1 one may see that in 1999 Playstation 2 (PS2) sold 1.41 millions of units. PS2 was released one month before the ending of the fiscal year, and so we decided to add this values to the 2010 fiscal year, and ignore that month, for simplicity purposes.

Following the rationale mentioned before, the values we considered were:

Parameter	Value	Description
K	24.57 mi$	The exercise price
y	178 mi$	Cash-flows of the new generation at starting point
σ	0.3	Instantaneous volatility
ϕ	0.614	Loss in old generation due to release of new one
r	4%	Risk-free interest rate
α	-5,4%	Growth rate of first product in Previous Generation period
α^P	-7,1%	Growth rate of first product in New Generation period
α^N	-8,9%	Growth rate of new product
α^*	-8,8%	Risk-neutral growth rate of first product in Previous Generation period
α^{*P}	-10,4%	Risk-neutral growth rate of first product in New Generation period
α^{*N}	-12,3%	Risk-neutral growth rate of new product

Figure 5.3: PS1 to PS2 case parameters

When Sony is in the market, in 1995, with the Playstation 1 it is receiving 72 million dollars (x), with a risk-neutral rate of growth of -0.088. Sony has the option to release the PS2 by paying the exercise price (K=24.57).

If Sony releases the PS2, the cash-flows of the PS1 will be $x(1-\phi)$.

Also, by releasing the PS2 Sony will receive its corresponding cash-flows: 178 million dollars (y) growing at a neutral-risk rate of -0.123.

The sales of the PS1 will only increase to a point, after which they will start to decrease as the product is not new and lost some of its appeal. In which point should Sony release the PS2 and start a new generation?

Imagining that Sony has the control of the market, and the entrance of a challenger does not affect the sales of the company. The project's trigger (the moment where the company should consider to release the PS2) is given by x_F^*.

Based on equations (3.16) and (3.15) we find the following output values:

Output	Value
x^*_F	44,55 mi$

Figure 5.4: The output values for the PS1 to PS2 case

The trigger value would, then, be 44,55 million dollars. Sony jumped from the PS1 to the PS2 when the cash-flows of the first product where 52 million dollars so, according to this model, Sony did not made the change in the right moment, but was close to it. We would like to recall that this model was simplified just for demonstrations purposes, and does not take into account other variables such as the effect of competition, management of stock of components, deals with suppliers, etc.

It is possible to notice that, contrary to an ordinary option to abandon, the value of the project increases with the value of x. This is due to the company being already active in the market. Indeed, as the cash-flows the company receives for being active with the first product increase, the less leaning the company is to release a new product (with all the costs of exercising that option) and give up part of those cash-flows. With cash-flows above the trigger the company decides to keep the option, as it holds value, and the value to wait is higher than the value of the project once implemented.

In Figure 5.5 we present the relationship between the trigger and y. The company should only release the new generation when the value of x and y are above the dark area. In this area it is not optimal to release the new generation. As it would be expected the higher the values of y, the sooner the company will release the new product (higher x).

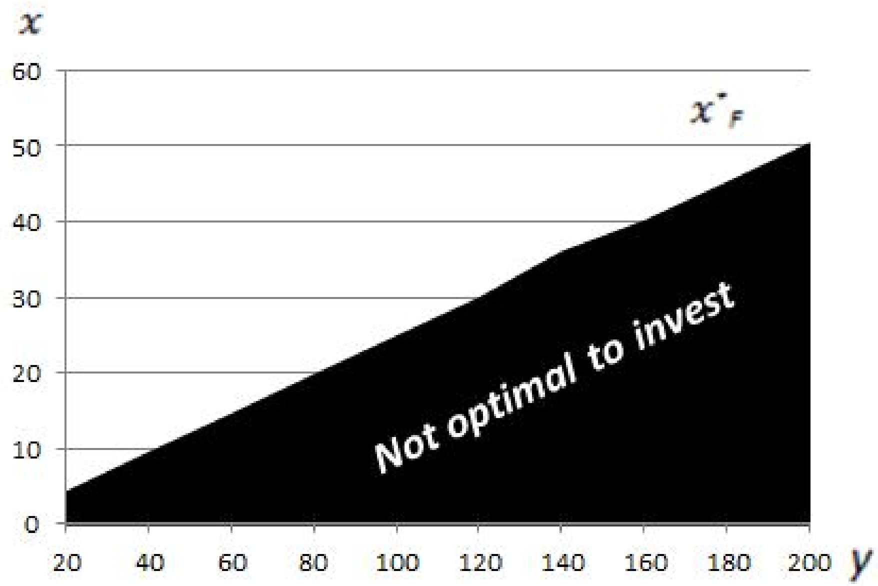

Figure 5.5: Old product and new one relationship (no competition)

5.2 PS2 to PS3 after the Xbox 360

This time Sony is already in the market with the PS2, having a major success (Sony Playstation 2 was the best console sold in history) and deciding when to release the PS3. Sony's sales and cash-flows evolve according to Figure 5.1 in Chapter 5.1. But this time Microsoft got ahead of Sony and released the Xbox 360, replacing their older console (Xbox), and starting a new generation (popular known as the HD generation).

This time Sony is in the market with the PS2, receiving 178 million euros (x) and has the option to enter the market, paying the same exercise price, and accepting a cut in the cash-flows of the current generation.

Following the rationale mentioned before, the values we considered were:

Parameter	Value	Description
K	24.57 mi$	The exercise price
y	111 mi$	Cash-flows of the new generation at starting point
σ	0.37	Instantaneous volatility
ϕ	0.3	Loss in old generation due to release of new one
h_1	12%	The loss in reputation afecting the old product
h_2	18%	The loss in reputation afecting the new product
r	4%	Risk-free interest rate
α	-8,9%	Growth rate of first product in Previous Generation period
α^P	-9,0%	Growth rate of first product in New Generation period
α^N	-4,2%	Growth rate of new product
α^*	-12,3%	Risk-neutral growth rate of first product in Previous Generation period
α^{*P}	-12,4%	Risk-neutral growth rate of first product in New Generation period
α^{*N}	-7,6%	Risk-neutral growth rate of new product

Figure 5.6: PS2 to PS3 with competitor case parameters

It took Sony a year to react by releasing their "HD" (High Definition) console (the PS3), and by the time they did, the Xbox 360 had already a fan-base, and Sony's consumers were disappointed to see that the company was not a pioneer in the "HD" era, and there was not many differences between the products to explain the one year delay.

So, Sony lost reputation, which affected not only the PS3 (reducing its possible cash-flows by h_2), but also the PS2 (reducing its possible cash-flows by h_1). This time our model has to incorporate competition, and its effects on the loss of reputation.

Based on equations (4.8) and (4.7) we find the following output values:

Output	Value
x^*_H	75.82 mi$

Figure 5.7: The output values for the PS1 to PS2 case with competition

The trigger value for Sony was 75.82 million dollars. Sony released the PS3 when the PS2 was still making 142 million dollars, so according to the model, Sony should had kept the option to release the PS3, and exercise it later, as doing so soon ended up by destroying the option's value. Sony PS2's sales were affected by the PS3, and this new product did not have enough success to compensate it.

If the company did not loose reputation after the release of the Microsoft Xbox 360, Sony's trigger would be 82 million dollars, which is the same as if we were using the model $F(x)$ in this situation, and the project value would be 1300 million dollars.

In Figure 5.8 we present the relationship between the trigger and y. The company should only release the new generation when the value of x and y are above the dark area. In this area it is not optimal to release the new generation. As it would be expected the higher the values of y, the sooner the company will release the new product (higher x).

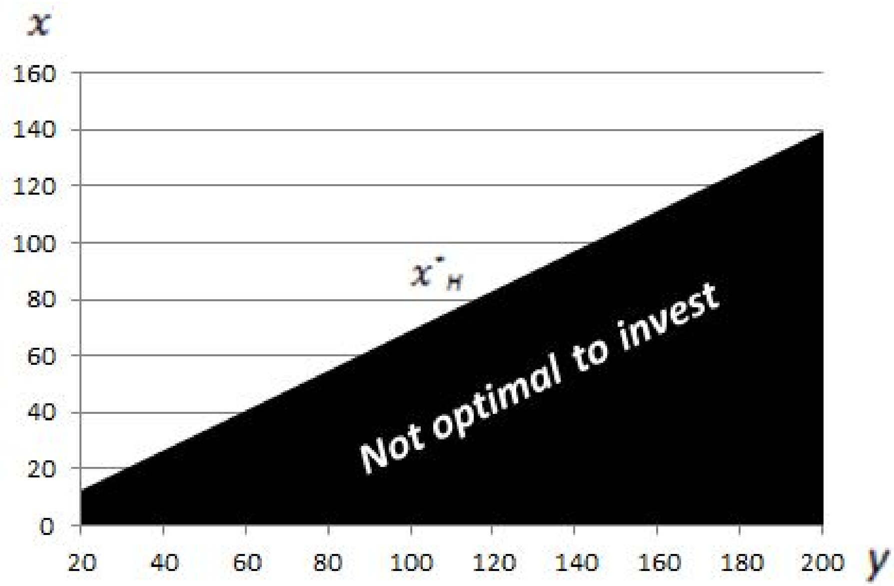

Figure 5.8: Old product and new one relationship (with competition)

5.3 PS2 to PS3 before the Xbox 360

In this chapter we will analyze the optimal timing for Sony to release the Playstation 3 (PS3), when there is a chance of being a first mover. In this case Sony is active in the market with the Playstation 2 (PS2) and has the chance of releasing the PS3. In order for Sony to release the PS3, it must pay a certain price, K (as the exercise cost) and give up part of the cash-flows of the PS2, σ (because the existence of the PS3 will have an impact on the PS2's sales, as part of the consumers will buy the new product instead of the old one).

If Sony is the first mover, they will be seen as an innovative company, and the model that best suits the evaluation of this project would be the model where the company controls the technology leap ($F(x)$), similar to the transition of the PS1 (the first Playstation) to the PS2 (seen in Chapter 5.1).

If some competitor enters the market of the new generation before Sony, the company will not be seen as a pioneer, losing some of its reputation. In this case the model that best suits this case is the model where the technology leap is exogenous to the model, after the entrance of a competitor ($H(x)$), similar to the transition of the PS2 to the PS3, after the entrance of the Microsoft Xbox 360 (seen in chapter 5.2.

In order to evaluate this project, we will use the model where the company does not control the technology leap, where there is a possibility of being a first mover (and acting as if the company controls that leap) or being a follower (and loosing reputation): $G(x)$.

We assumed the parameters to be the same as in the 5.6, and $\lambda = 0.2$ as a company usually enters the market every five years.

Based on equation (4.15), equation (4.16) and equation (4.17) we found that x_G^* is 141.66 million dollars. The value of x_G^* is higher than the value of x_H^*, because the fear of being a second mover should hurry the company to exercise its option. Sony released the PS3 when PS2's cash-flows were 142 million dollars, which means the company made the right move by not releasing it earlier and keeping the option, but did not make the right move by releasing the PS3 by then as the Microsoft had already entered the market, and the company was left with option $H(x)$ which trigger is x_H^*=75.82 million dollars.

If there was not any probability of a rival entering the market (λ=0), or if the company did not loose reputation in any of its products (h_1 and h_2=0) the trigger would be 82 million, which is what we obtain if we apply the model $F(x)$ to this situation.

In Figure 5.9 we present the relationship between the trigger and y. The company should only release the new generation when the value of x and y are above the dark area. In this area it is not optimal to release the new generation. As it would be expected the higher the values of y, the sooner the company will release the new product (higher x).

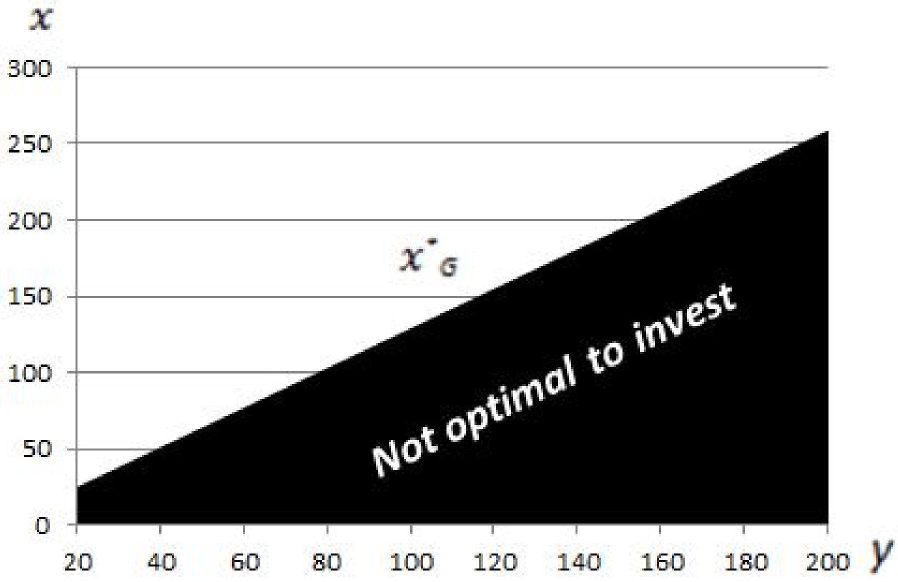

Figure 5.9: Old product and new one relationship (hidden competition)

5.4 Comparative statics and sensitive analysis

Since the parameters chosen were based on fallible assumptions, we decided to do a sensitive analysis to find out how the model would behave if the parameters were different from those we chose.

The following table summarizes the behavior of the triggers, according to changes in the assumptions:

	σ			ϕ		h_1			h_2			λ		
	0.1	**0.3**	**0.4**	**0.3**	**0.6**	**0**	**0.2**	**0.5**	**0**	**0.2**	**0.5**	**0**	**0.2**	**1**
x^*_F	61	45	37	78	46	-	-	-	-	-	-	-	-	-
x^*_H	109	85	72	76	38	67	84	133	93	74	46	-	-	-
x^*_G	216	160	134	142	67	127	153	223	91	146	206	82	142	242

Figure 5.10: The value of the triggers with different values on the parameters

As it would be expected the increase in volatility (σ) decreases the value of the trigger, as the company will exercise the option later.

An increase in the "loss in old generation due to release of new one" (ϕ) decreases the value of the trigger, because the company will exercise the option later, as doing so would have a bigger impact in the sales of the first product.

As the effect of the loss of reputation in the old product increase so does the trigger. This is because the loss in the sales of the old product will rush the company to release a new generation to compensate this loss.

The increase of h_2 leads to an increase in the trigger of the company when the effect is irreversible, but leads to a decrease in the trigger of the company when the competitor has not yet entered the market. If the competitor has already entered the market the company should see the loss in the new generation as a sunk cost, and this should decrease the appeal to release a new product. If the competitor has not yet entered the market, but there is the possibility of doing so, the company should release the new generation sooner, trying to avoid the effect of the reputation loss.

At least, as it would be expected, as the chances of rivals entering the market increases so will the trigger of the company, leading to an early increase to avoid the reputation losses.

Chapter 6

Conclusions

Following the research done in Real Options we developed two new models whose purpose was to determine the optimal time for a technological company to jump from one generations of product into another. These two models contributed to the field of investigation in Real Options by introducing some innovations, combining the stochastic evolution of the cash-flows with the product's life cycle, and seeing the option to enter the market as a put option, by which the company has the option to abandon the current generation, receiving in return the value of the new one.

We analyzed the value of the high-tech market, perceiving that this market is largely based upon research and development, with current high rates of growth on the development of new technologies and discoveries being made. We also described how the consumers tend to have a fast-paced adoption of new products, leaving the old ones with a small share of the market. This combined with the costs of releasing a new product make it decisive to correctly estimate the perfect moment to start a new generation, as there are major variables considerations to be aware of, such as the level and speed of acceptance of the new product, or the effect of the complementary products and even marketing issues, among other variables.

In order to gain the needed knowledge to study this subject we reviewed some research conducted before, such as the beginning of the Real Options theory, some models used to evaluate options when the cash-flows are stochastic, others were the focus is on the product life-cycle, we studied researches about innovation (what it is, what is the impact and how it is accepted by consumers), and ended our research with studies about the strategy used in high-tech industries when releasing new products.

In our first model we introduced a model where the company had the control of the technological leap, being capable of determining when to start a new generation. In this case the company is acting in the market with the current generation but has the option of giving up a part, or the total amount, of the cash-flows being received by that product (because the old product may share the market with the new one) as well as an exercise cost (the total amount of costs demanded to introduce and commercialize the new product), in exchange of the value of a new generation. When the company exercises the option it will receive the new project's value, loosing the exercise price and the old product will loose immediately part of its cash-flows, and will evolve with a different growth rate. We found out that, in order for the model to make sense when the company exercises its option, one of two things must happen: either the company is investing because of the value of the new product's cash-flows, since its older product will be affected by this new one (when the value of the new generation exceeds the exercise price), or the company is investing because of the synergies the new generation will have with the old one when both share the market (when the exercise price is higher than the value of the new generation).

In the second model we introduced the effect of competition. This time, the company does not fully control the technological leap, and does not determine when to start a generation. In this model, the company is active in the maket with a product, but faces the risk of competition, with others being pioneer to enter the new generation market (by releasing a new product first), and leaving the company with only the option to settle for being the follower.

In this reality the company has an option to enter the market as being the first-mover, but that option is only valid until a competitor decides to move first. In that case the company looses that option, and is left with the option of entering the market, where there is already competition.

If the company looses the opportunity to be the first mover, it will have consequences in the firm's reputation, which will influence its cash-flows, reducing them by an amount between 0% and 100%. We saw how the models contemplates different possibilities of loss for each product (the decrease in reputation may affect the new product and the old one by a different dimension).

The model was obtained by determining what happens when the competitor has entered the market, and then including that in the model where there is only the possibility of that happening.

We also pointed that if there is not the probability of a rival entering the market, or if this entrance does not affect the company, then all the models would behave as the model where the company controls the technological leap.

In the fifth chapter we used a real-world example: the video-game industry, with Sony being the company analyzed. The goal was to create three different realities and evaluate how the model suits this market.

In the first scenario we evaluated the transition from the Playstation to the Playstation 2, imagining that Sony does not have competition. We concluded that the company was close to its trigger when it released the new product (the theoretical optimal timing to exercise the option would be when the cash-flows were almost 45 million dollars, but the company exercised when they were 52 million). Also we saw how the value of the project increases with the value of the cash-flows, even though the company holds a real option to abandon the first generation.

In the second scenario we re-evaluated the transition from the Playstation to the Playstation 2 (PS2), considering that a rival (Microsoft Xbox 360) has already entered the market, affecting Sony's reputation and the cash-flows generated by Playstation 2 and Playstation 3 (PS3). In this case Sony had the option to abandon part of the cash-flows of the PS2 in exchange for the cash-flows of the PS3, knowing that both consoles will sell less, as the company is not seen thenceforth as a pioneer. In this case Sony should've exercised the option when PS2's cash-flows were almost 76 million dollars, but the company rushed and released the new product when the old one still had cash-flows of 142 million dollars.

In the third scenario we evaluated the Playstation 2 to the Playstation 3, when the competition has already entered the market, with the loss of reputation affecting Sony's products. In this case Sony had the option to enter the new generation market being a first mover, but with the probability of a competitor entering the market in any time, turning the company's option to be a first mover into an option to be a follower. This fear of the entrance of competition increases the optimal timing to invest, so the company should exercise earlier. We saw that Sony did the right move by not exercising the option before the release of the Microsoft Xbox 360, but then released the PS3 too soon, when the only option was to be a second mover. We also saw that if the probability of a rival entrance, or its effects on Sony's cash-flows, was null, the trigger would be the same as in the model where the company controls the technology leap.

To conclude we conducted a sensitive analysis and verified that the increase in volatility and increase in the loss of the old product due to the introduction of the new one decrease the trigger of the company, making it invest later. The increase in loss in reputation in the old product due to the entrance of a rival, and the increase in the probability of a rival entering, increase the trigger, making the company exercise the option earlier to avoid this losses. The increase of the damaged done to the reputation of the new product due to the entrance of a rival before the company has two effects: it increases the trigger of the company if the rival has not yet entered, making the company release the product earlier to avoid being a follower; it decreases the trigger, if the rival has already entered the market, and the losses ar a sunk cost, making the company exercise the option later.

For further studies we would suggest using these models in areas different from the video-game industry (or even in other areas besides technology) and trying to develop a model where the innovation that can lead to a new generation is endogenous in the model.

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